Exploration Life Support

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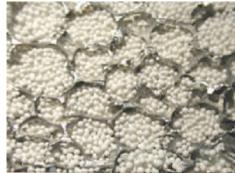
The Exploration Life Support (ELS) project addresses the need for development of new and advanced life support technologies for exploration vehicles. ELS goals are to provide technology options to supply atmospheric gas, potable water, and waste management that minimize the need for mission resources. The ELS project is managed from Johnson Space Center (JSC) but involves efforts at other NASA field centers, as well as industry and university research labs. Other NASA centers that manage parts of the ELS project are Ames Research Center, Marshall Space Flight Center, Glenn Research Center, and Kennedy Space Center.

ELS efforts have been focused to address critical life support functions required by the Crew Exploration Vehicle (CEV), the lunar lander, and the Lunar Outpost (LO) vehicles and missions. The CEV and lander missions are relatively short duration, with active periods of less than 20 days. Therefore, recovery of atmospheric or water resources is not essential for the CEV and Lunar Surface Access Module (LSAM) missions. The LO missions are planned to extend over 6 months, making regeneration of atmospheric and water resources critical to significantly decrease total mission resource requirements.

JSC manages the efforts to develop a technology that is included in the CEV baseline design to address the needs to remove both carbon dioxide (CO₂) and humidity from the cabin atmosphere. The ELS CO₂ and Moisture Removal Amine Swing-bed (CAMRAS) technology uses an amine sorbent to remove both CO₂ and water vapor from the atmosphere. The system vents absorbed CO₂ and moisture when exposed to vacuum, regenerating the capability of the

amine sorbent to absorb CO₂ and moisture from cabin atmosphere. The amine sorbent, packaged in a honeycomb support structure in the CAMRAS unit, is shown in figure 1.

Fig. 1. Solid Amine Sorbent in Thermally Conductive Metal Foam exposes the amine to air flow and thermally connects layers.



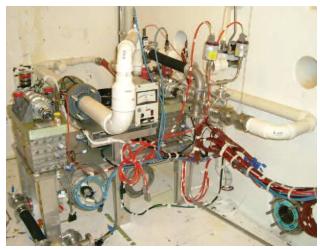


Fig. 2. CAMRAS Units as integrated for CEV-related testing.

The packaging of the solid amine in each CAMRAS takes advantage of the exothermic heat of reaction during the adsorption phase by adding energy to the endothermic reaction during the desorption phase. The energy is transferred by thermally connecting layers that alternate between adsorbing and desorbing cycles. Two prototype CAMRAS units have been developed (figure 2). The first unit was successfully tested in a CEV-relevant environment to confirm that the technology can provide the needed CEV CO₂ and moisture control function. The second unit has a modified design that includes the capability to flow a sweep gas through the unit when venting to vacuum is not possible to desorb CO2 and moisture. This condition may be required while the CEV is operated before launch. Testing of the modified design has been completed at the manufacturer. Preparation for planned testing of the two CAMRAS units in the CEV-representative environment is underway.

Other ELS efforts related to the CEV and LSAM vehicles have focused on trace contaminant control, potable water disinfection, urine pretreatment, and human waste collection.

LO ELS technology development efforts are addressing the recovery of waste atmosphere gases, including: CO₂, moisture (water vapor) and hydrogen (H₂); wastewater; and stabilization, storage of waste products, and recovery of water from waste. CO₂ and

moisture are crew waste gases. H₂ is a waste gas that is produced in the expected process of electrolysis of water to provide makeup oxygen for the crew. ELS efforts have addressed development and testing of a Sabatier reactor with mechanical and solid-state temperature-based compressors linked with an International Space Station CO₂ removal unit. The Sabatier prototype unit uses compressed CO₂ and waste H₂ to form methane and water. The water is recovered and reused, while the methane is vented to vacuum. Testing of the integrated set of technology units was completed successfully in 2006. A more advanced version of the CO₂ collection and Sabatier technologies was developed and tested at the manufacturer and is planned to be tested in a representative environment at JSC.

Wastewater recovery has focused on distillation and membrane processes. Distillation processes generate water near potable quality by evaporating wastewater to produce purified distillate and concentrated brine waste. A prototype that efficiently removes contaminants by linking evaporation and condensation in cascaded stages to provide water was developed, passed testing at the manufacturer, and delivered to JSC for performance testing and characterization. Testing was initiated for the Cascade Distillation Subsystem, shown in figure 3, in the summer of 2007 and will last approximately 12 months.

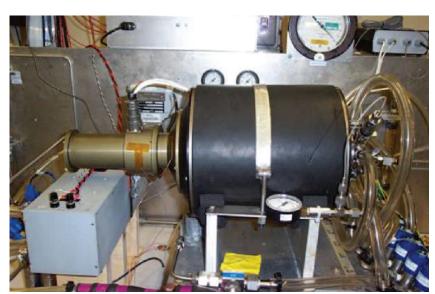




Fig. 4. The Air Revitalization Test and Evaluation Facility as configured for the CEV CAMRAS system phase 3 testing.

The JSC ELS Flight Experiment and Integrated Test element addresses ground and flight experiments. The ground test labs for air revitalization and water recovery technology evaluation provide an environment as close to expected flight environments as possible. Testing in the representative environment confirms that technologies can accomplish their planned Constellation vehicle life support function. The Air Revitalization Test and Evaluation Facility, as configured for CAMRAS testing, is shown in figure 4. The chamber shown in the background of figure 4 was configured to accurately represent the volume of the

CEV cabin. The attached Human Metabolic Simulator, in the foreground of figure 4, simulates the metabolic inputs and use of atmospheric gases.

JSC also addresses the need to evaluate technologies or components in scenarios, combinations, and/or environments not possible in ground facilities. Several flights of ELS equipment on micro- and reduced-gravity-simulating airplane flights have been conducted in that past

Fig. 3. Cascade Distiller and Thermoelectric Heat Pump as configured for test of wastewater recovery performance.

Exploration Life Support

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2 years. Those flights verified the performance of components of ELS technologies in short-duration micro- and partial-gravity environments. These flight experiments also identified problems with some components. ELS researchers are shown during flight testing of ELS equipment in figures 5 and 6.

Evaluation of ELS technologies for performance also requires analytical approaches to address scenarios and combinations of equipment beyond the scope of laboratory testing. The ELS System Integration, Modeling, and Analysis (SIMA) group has addressed the analytical need by using information from the theory, design, and testing of a technology to create a computer models. When incorporated with other ELS or existing life support technology models in an integrated life support system, the performance of the technology can be evaluated for its contribution to the overall life support system. The expertise of the SIMA group has been recognized across NASA and was used to address analytical life support needs for Constellation CEV and lunar programs.



Fig. 5. ELS researchers floating during a microgravity period of test of a static water/air separator.

